EPSC Abstracts
Vol. 11, EPSC2017-581-1, 2017
European Planetary Science Congress 2017

Characterising Jupiter's Temperatures, Aerosols and Ammonia via VLT/VISIR Spatial Mapping 2016-17

P. T. Donnelly (1), L.N. Fletcher (1), G.S. Orton (2), H. Melin (1)
(1) Dept. of Physics and Astronomy, University of Leicester, UK, (2) Jet Propulsion Laboratory, California Institute of Technology, USA

Abstract

The VISIR mid-IR imager (5-25 µm) on the Very Large Telescope (VLT) has been providing infrared spatial and temporal support for NASA's Juno spacecraft, constraining atmospheric thermal conditions in the upper troposphere (100-700 mbar) and stratosphere (1-10 mbar). Our pre-Juno-arrival dataset (January-August 2016) demonstrated that Jupiter's North Equatorial Belt (NEB) began a northward expansion in late 2015, consistent with the 3-5 year cycle of NEB activity. VISIR detected two new thermal waves during this period; an upper tropospheric wave in the mid-NEB and a stratospheric wave centred on the eastward jet at 23.9°N. The latter was quasi-stationary and both waves are morphologically similar to those observed during the 2000 expansion event by Cassini. We now extend this analysis to coincide with Juno's perijove encounters, once every 53.5 days. We report (i) the continued existence of the mid-NEB wave; (ii) evolution of Jupiter's North Temperate Belt (NTB) following the October 2016 outbreak; and (iii) complex thermal variability associated with a mid-SEB outbreak during 2017. We discuss zonally-averaged temperatures, aerosols and ammonia distributions derived from VLT data (taking centre-to-limb variations into account), comparing the upper-tropospheric aerosols and ammonia to the findings of Juno's near-infrared and microwave observations.

1. Introduction: Variability

The VISIR observations during the Juno epoch contribute to a time-series of VLT imaging that now spans a full Jovian year (2006-2017). Observations at eight narrow-band channels sense stratospheric temperatures (7.9 µm), tropospheric temperature (13.0, 17.6, 18.6, 19.5 µm), aerosols (8.6 µm) and ammonia (10.7 and 12.3 µm), and are inverted via our optimal estimation retrieval algorithm, NEMESIS [1]. This long time-series has allowed us to investigate thermal variability associated with fades and revivals of the South Equatorial Belt [2, 3], and the recent expansion of the NEB [4]. In this paper, we report the findings of the NEB and the activity at other latitudes (the NTB and SEB) during the Juno epoch, and use the data to provide cloud-top estimates of temperatures, ammonia and aerosols to compare to Juno's perijove observations.

2. Thermal Field in 2017

The 2015/16 NEB expansion was unusual. Previous NEB expansions have encircled the entire globe, but this one stalled after February and began to regress from both ends. At this point, it spanned 140° of longitude and was 4° further northwards than the non-expanded sector. VLT/VISIR images in March 2016 suggest northern edge beginning to grow dim at 8.6µm (a re-establishment of the aerosol opacity over the NTropZ). By the time of Juno's arrival, the expanded sector had returned to normal and the 8.6µm-dark NTropZ again extended fully around the planet.

During the expansion, two waves were identified: a mid-NEB thermal wave that appeared quasi-stationary and showed an anticorrelation between temperatures and upper tropospheric haze reflectivity; and a stratospheric wave from 20-30ºN. Both are similar to waves observed during previous expansion cycles and both persisted after Juno's arrival. The mid-NEB wave remains present today (Fig. 1).

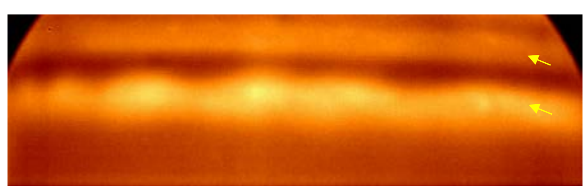

Figure 1: VLT/VISIR 17.65-µm observation for 11 Jan 2017, probing upper-tropospheric (150mbar) temperatures showing persistent wave activity over the NEB region. NEB and NTB shown by yellow arrows.

We also report on variations at Jupiter's northern temperate latitudes (specifically the NTB), where four plumes erupted in October 2016 and may have altered temperatures and composition in this region. Our inversions of VISIR data will produce zonally-averaged temperatures in the NTB before and after the plume outbreak, allowing comparison of these conditions. Furthermore, the VISIR observations in 2017 have continued to track an outbreak of moist convective activity in the mid-SEB: we will describe the processes at work shaping this complex region (Fig. 2).

Figure 2: VLT/VISIR 8.6-µm observation for 10 Jan 2017, probing cloud-tops (650mbar). The NTB and the outbreak in the mid-SEB are denoted by the yellow arrows.

3. Equatorial Ammonia – Abundances and Distribution

Recent findings from Juno suggest that there is a peak in ammonia at the equator, with the region over the NEB also being more depleted than SEB. This is consistent with previous thermal-IR spectroscopic analyses [5, 6], which suggest strong equatorial upwelling, but have confirmed that this zone of elevated ammonia persists to great depths below the clouds. By inverting zonal-mean VISIR observations, taking into account their dependence on emission angle, we will assess whether VISIR imaging alone is sensitive to this equatorial ammonia maximum, allowing us to maps its variation with longitude and with time through the full decade-long dataset.

Summary and Conclusions

VISIR thermal imaging provides a regular source of information on the temperatures, aerosols and ammonia distributions associated with the phenomena studied by Juno. They also place the Juno epoch into the wider context of Jovian variability over a full ~12 year orbit. We expect also to have observations covering perijoves 6, 7 and possibly 8. Future work will include the use of N-band spectroscopy to further constrain chemical abundances, and direct comparisons with deep structures observed at microwave wavelengths.

Acknowledgements

PTD was supported by an STFC studentship; Fletcher was supported by a Royal Society Research Fellowship at the University of Leicester. The UK authors acknowledge the support of the Science and Technology Facilities Council (STFC).

References

[1] Irwin, P., Teanby, N., de Kok, R., Fletcher, L. N., Howett, C., Tsang, C., Wilson, C., Calcutt, S., Nixon, C., Parrish, P., The NEMESIS planetary atmosphere radiative transfer and retrieval tool, Journal of Quantitative Spectroscopy and Radiative Transfer, 109(6), 461 1136–1150, 2008.

[2] Fletcher, L. N., Orton, G. S., Rogers, J. H., Simon-Miller, A. A., de Pater, I., Wong, M. H., Mousis, O., Irwin, P. G. J, Jacquesson, M., Yanamandra-Fisher, P . A., Jovian temperature and cloud variability during the 2009-2010 fade of the South Equatorial Belt, Icarus, 213, 564–580, 2011.

[3] Fletcher, L.N., Orton, G.S., Rogers, J.H., Giles, R.S., Payne, A.V., Irwin, P.G.J., Vedovato, M., Moist Convection and the 2010-2011 Revival of Jupiter's South Equatorial Belt. Icarus 286, 94–117, 2017a.

[4] Fletcher, L. N., Donnelly, P. T., Orton, G. S., Sinclair, J. A., Melin, H., Rogers, J. H., Greathouse, T.K., Kasaba, Y., Fujiyoshi, T., Sato, T.M., Fernandes, J., Irwin, P.G.J, Giles, R.S., Jupiter's North Equatorial Belt expansion and thermal wave activity ahead of Juno's arrival, Geophys. Res. Lett., 44, 1–9, 2017b.

[5] Achterberg, R. K., Conrath, B., Gierasch, P. J., Cassini CIRS retreivals of ammonia in Jupiter's upper troposphere, Icarus, 182, 169-180, 2006.

[6] Fletcher, L. N., Greathouse, T.K, Orton, G.S., Sinclair, J. A., Giles, R. S., Irwin, P. G. J, Encrenaz, T., Mid-infrared mapping of Jupiter's temperatures, aerosol opacity and chemical distributions with IRTF/TEXES, Icarus, 278, 128–161, 2016.